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ABSTRACT

This study is an exploratory attempt to test the idea that individual differences in the rate of acquisition of an original discrimination learning are related to individual differences in the capacity to estimate the passage of time. Included is a review of the literature on the psychology of time which indicates that underestimation of time is associated with predominance of excitatory processes and overestimation time is associated with inhibitory processes. A discrimination learning problem was administered to 91 male college students to test the hypotheses that time estimation is positively related to the number of trials required to reach (1) the original discrimination learning criterion, (2) the reversal learning criterion, and (3) the total discrimination-shift criterion. Results support two of these hypotheses and the theoretical analysis of the relation between time estimation and discrimination learning. It was concluded that the rate at which a discrimination is learned is a function of the amount of excitatory predominance as measured by the time estimation task, and that a fundamental process which occurs during discrimination learning is the rate at which excitatory processes come to be conditioned to a predominance over inhibitory processes. (GO)

RELATIONSHIP BETWEEN HUMAN TEMPORAL BEHAVIOR AND DISCRIMINATION-REVERSAL LEARNING[1]

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Introduction

The present study represents an exploratory attempt to utilize the intervening variables of excitation and inhibition as psychological-level processes to account for observed individual differences in both human discrimination-reversal learning and human temporal behavior.

The specific relationship chosen for investigation in this study, is the relationship between individual differences in the successful acquisition of a complex form of human discrimination-reversal learning, adapted from Kendler and Mayzner, 1956 and individual differences in a time estimation task employing a variation of the method of reproduction.

Although there is no immediately apparent reason to postulate the existence of a relationship between these two highly complex and distinctly different forms of human behavior, an attempt will be made to demonstrate that historical precedence exists for the use of the twin concepts of excitation and inhibition as intervening variables which can not only be used to postulate that such a relationship indeed exists, but from which biphasic, directional hypothesis can be generated and put to test.

The Russian psychologist, Sechenov, was (according to Von Bekesy writing in 1969), the discoverer of central excitation and inhibition. In 1863, Sechenov postulated the twin concepts of cortical excitation and inhibition to account for the psychic activity of the higher nervous centres and established in his monograph entitled the Reflexes of the Brain a tradition of objectivity still present in Russian physiology and psychology. The work of Sechenov has not received a great deal of attention (in America); however, in 1967, Kimble wrote the following words: "There is little doubt, had the writings of Sechenov been more accessible to the West, this early physiologist would have been regarded as one of the giants in the history of psychology." (Kimble, 1967, p. 21)

Pavlov (1927) not only acknowledged the strong influence

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of Sechenov, but was also one of the first workers to experimentally demonstrate the elaboration of precise discriminatory responses. Pavlov developed a theoretical framework wherein the acquisition of the correct discriminatory response was viewed as a function of the experimentally established facts of conditioning, extinction and stimulus generalization. The basic theoretical mechanism responsible for the behavioral fact of acquisition was postulated as being a delicately balanced interaction between the presumed cortical processes of excitation and inhibition, a theoretical position in accord with Sechenov's earlier formulations.

To this day, Pavlovian techniques, methods and experimental results continue to enjoy an enthusiastic reception in America; however, the Sechenov-Pavlov strategy of inferring neurophysiological mechanisms from behavioral data is still rejected by many American workers. Whatever the final merits of this position on the ancient mind-body problem prove to be, one thing is clear: Pavlov established the use of the twin concepts of excitation and inhibition as physiological-level theoretical processes to explain the observed behavioral facts of discrimination learning acquisition.

In 1929, just two years after the appearance of the Anrep translation, Hull was already in print developing a functional interpretation of the conditioned reflex wherein the concepts of "excitatory phase" and "inhibitory phase" played a crucial role in his attempts to understand both conditioning and discrimination learning.

Spence (1936, 1937a, 1937b) and Hull (1939, 1943, 1950, 1952) developed the American version of the conditioning-extinction theory of discrimination learning wherein the acquisition of the correct response was viewed to be dependent upon an underlying conditioned predominance of excitatory potentials over inhibitory potentials. The essence of this theory, which was the original formulation of the single unit theory currently being employed by the Kendlers (1969), is the notion that positively-rewarded trials are conditioning trials, that non-reward trials are extinction trials and that stimulus generalization operates to produce excitatory and inhibitory gradients about these respective stimulus conditions. In 1961 Kimble presented a clear and succinct summary of this theory which includes the following six assumptions.

1. Every positive trial represents a reinforcement conditioning trial which leads to an increment in the excitatory potential to repeat the response,

2. Every negative trial represents a non-reinforcement extinction trial which leads to an increment in the inhibitory potential not to respond,

3) Stimulus generalization operates to generalize both tendencies to other stimuli,

4) The magnitude of the excitatory potential must exceed that of the inhibitory potential if the correct response is to occur,

5) The excitatory and inhibitory tendencies interact algebraically, and,

6) The discriminatory responses are the resultant of the resolution of these competing tendencies in favor of the reaction to the stimulus which has the stronger tendency conditioned (or generalized) to it.

The present study represents an exploratory attempt to test the notion that individual differences in the rate of acquisition of an original discrimination learning are a function of the individual differences in the capacity of organisms to develop the necessary strength of excitatory potential which must come to be predominant over existing inhibitory potentials. If, as the above mentioned theories postulate, the speed of acquisition is a function of the speed to which conditioned excitatory potentials come to be predominant over inhibitory potentials: then it should follow that individual organisms who enter the situation with pre-existing tendencies which allow for the faster build-up of excitatory potentials will acquire the correct discriminatory response in less trials than individuals who are not in possession of these presumed tendencies. In essence, the present study views the acquisition of the correct response as an interaction between organism and environment wherein the speed of learning is a function of individual differences in conditionability and attempts to apply the model of excitation-inhibition balance to explain these observed individual differences.

Before moving to a consideration of time estimation as the possible means of assessing individual differences in excitation-inhibition balance, it should be concluded that no unbiased review of the history of discrimination learning can be made without realizing that a striking similarity exists between the theoretical positions of the Sechenov-Pavlov view and the Spence-Hull formation. Both theories saw the acquisition of a discrimination as arising from the three experimental facts of conditioning, extinction and stimulus generalization. The essential difference between these two positions was in the use of the concepts of excitation and inhibition.

Sechenov and Pavlov employed the concepts of excitation and inhibition as physiological-level hypothetical constructs which referred to the activity of the cerebral cortex.

Spence and Hull utilized the concepts of excitatory and inhibitory potentials as psychological-level intervening variables which should not carry any surplus meanings -- especially Spence who warned against "physiologizing" to the physiological-level substrate! The present study follows the Spence-Hull tradition in as much as the concepts of excitation and inhibition are herein used as psychological-level intervening variables.

In 1912, Feokritova, working at the Pavlovian laboratories, demonstrated that by feeding a dog at precise time intervals of 30 minutes it was possible to elaborate a "conditioning to time" wherein time was seen to act as the conditioned stimulus and whereby a very accurate time estimation could be produced by her canine subjects. In 1943, Hull showed that this procedure of temporal conditioning also produces in human subjects unmistakable evidence of the same capacity. Pavlov had assumed that time estimations arise through the interactions of the processes of excitation and inhibition. Powerful evidence for his contention that alternating phases of excitation and inhibition are responsible for time estimations was provided by a further experiment by Feokritova wherein a compound stimulus was employed. The animal was fed every 30 minutes with the addition of the sound of a metronome applied a few seconds before the food. After successful conditioning to this compound stimulus of time plus sound was established, test trials using the metronome alone were begun. If the sound was applied at the 5th minute, no salivation occurred. If the sound was applied at the 20th minute some salivation occurred, applied at the 25th minute the effect was greater still. At the 30th minute the reaction was complete. According to Fraisse (1963), the inhibitory process in this case is time-linked. The action of an inhibitory process upon the excitatory process necessary to produce the reaction moves from complete inhibition at the 5th minute, through stages of lessened inhibitory effect to the final stage where the full excitatory response occurs. This simple demonstration provides strong evidence for the concept that the reaction potential available at any given moment is the resultant of the interacting phases of excitation and inhibition. It also sets the precedent for the view espoused within the present study that time estimations produced by human subjects may be viewed as the resultant of the processes of excitation and inhibition.

In 1963, Fraisse summarized the literature of drug effects upon time estimation in humans. In general, stimulants and excitatory drugs accelerate the perceived passage of time and produce underestimations of standard time periods; while sedatives and other inhibitory drugs slow down the perceived passage of time and produce overestimations.

From these observations and others contained in the literature of the psychology of time, the following assumptions were formulated:

1) Underestimation of time in normal, undrugged human subjects is associated with a predominance of excitatory processes, and

2) Overestimation of time in normal, undrugged human subjects is associated with a predominance of inhibitory processes.

These two assumptions must obviously remain, at present, as hypothetical constructs which seek to establish a theoretical association between observed time estimation behaviors and underlying levels of excitation-inhibition balance.

From the preceeding considerations the following hypotheses were generated and put to test:

Hypothesis I - Time estimation is positvely related to the number of trials required to reach the original discrimination learning criterion.

Hypothesis II - Time estimation is positively related to the number of trials required to reach the reversal learning criterion.

Hypothesis III - Time estimation is positively related to the number of trials required to reach the total discrimination-reversal shift criterion.

Underlying these hypotheses are the following theoretical assumptions:

1) Individuals who tend toward a predominance of excitatory processes should underestimate time and also learn both tasks in fewer trials, and

2) Individuals who tend toward a predominance of inhibitory processes should overestimate time and should learn both tasks in a greater number of trials.

The subjects were 91 male undergraduate and graduate college students attending New York City Colleges. Nine subjects failed to reach both criterion, since the design called for an analysis amongst successful learners, the final sample consisted of 82 subjects.

In the procedures for time estimation, the method of reproduction was used to give each subject 18 separate time estimations. Ten, 15 and 20 second standard time intervals were randomly presented 6 times each to every subject. The

procedure required the subject to hear one sound - tap of pencil - signalling the beginning of a standard interval - then a second tap marking the end of the interval - and then the subject reproduced the time interval by tapping a third time when he judged the second interval to be equal to the standard.

The procedure employed to measure discrimination-reversal learning was equivalent to that used by Kendler and Mayzner in 1956. Essentially, the first learning was to sort the response cards to a correct response which consisted of a radius of a circle parallel to the line on one of the two stimulus cards always present. The reversal shift procedure was an intra-dimensional shift wherein the correct response shifted without the subject's knowledge from parallelism to perpendicularity between the stimulus and response cards.

Results: Hypothesis I was tested and supported by the following results which can be seen in Table 1 of the hand-out sheet. The 48 subjects who underestimated time required a mean number of 12.93 trials to reach criterion, while the 34 subjects who overestimated time required 27.73 trials to reach the original discrimination criterion. Although based upon the same mathematical assumptions, the T-test and the Pearson correlation give different kinds of information. The T-test tells us that underestimators do indeed learn at a significantly faster rate than do the overestimators ($p<.005$). The Pearson r becomes the basis for stating that a positive, non-zero correlation exists between time estimation and original acquisition of the discrimination ($r=.05$, $p<.005$).

When the hypotheses were originally formulated regarding time estimation and reversal learning, an implicit assumption was that within the discrimination task, original and reversal learning would be correlated. However, the actual correlation between original and reversal learning is merely 0.15, which is not significantly different from zero. This lack of correlation between the two forms of learning may perhaps explain why the results of the reversal learning cannot be predicted from the time estimation scores. The results appear in Table 2 of the handout sheet. Therefore, Hypothesis II was not upheld by the results.

The test of Hypothesis III is shown by the results of Table III, wherein it may be seen that the underestimators reached the total learning criterion in 24.29 trials less than the overestimators. The p value for both t and r being less than .005.

The theoretical explanation herein proposed to account for the observed learning superiority of the underestimators, is that such subjects enter the original learning situation

with an already existing tendency towards the predominance of excitatory processes. As the conditioning proceeds, the predisposition of these subjects acts to facilitate the rate at which excitatory processes come to predominate over inhibitory processes. It may be concluded from the above results that one contribution of the present study is the demonstration that within a total group of 82 human subjects, all of whom are successful performers of the same task, a dichotomous grouping along a temporal dimension leads to significant differences in the rate at which original acquisition of a complex discrimination learning task occurs. Furthermore, the direction of that difference is in the direction predicted from an analysis based upon the use of excitation-inhibition concepts as intervening variables.

Perhaps the most powerful evidence which has emerged from the present study in support of the theoretical position herein adopted is presented in Table 4 of the handout sheet.

If the rate at which excitatory processes become predominant over inhibitory processes is truly a good account of discrimination learning, then it should follow that subjects possessing the greatest propensity toward excitatory predominance should learn fastest and that a continuum should exist that starts with these individual subjects, passes through intermediate stages, and ends with those subjects possessing the least propensity towards excitatory predominance. The analysis of time estimation scores into consistency scores, as shown in Table 4, provides the behavioral evidence necessary to support the above hypothesis. The results of Table 4 are reproduced below:

TABLE 4: Consistency Scores

	Consistency Scores			
	-3	-1	+1	+3
Trials to Original Criterion	11.33	14.85	20.64	33.10

A consistency score represents the degree to which an individual subject is consistently an underestimator or overestimator. Each consistency score represents the algebraic sum of the means which resulted from the reproduction of the 10, 15, and 20 second standard time intervals. Thus, a score of -3 means that all three time intervals were underestimated, while a score of +3 means that all three time

intervals were overestimated. The intermediate scores represent situations where two of the three were similar. As may be seen in Table 4, a continuum exists such that those subjects which are the most consistent underestimators are also the fastest learners and in which increasing amounts of overestimation are associated with increased trials required to learn. The theoretical interpretations which are herein attached to these findings are the following:

1) Subjects who possess the strongest tendency towards a predominance of excitatory processes (-3 scores) display the greatest propensity towards the rapid conditioning of excitatory processes over inhibitory processes (as manifested by the fact that such subjects require only a mean of 11.33 trials to criterion),

2) Subjects who display the weakest tendency towards a predominance of excitatory processes (+3 scores) display the least propensity towards the rapid conditioning of excitatory processes over inhibitory processes (as manifested by the fact that such subjects require a mean of 33.10 trials to criterion),

3) Subjects who display intermediate tendencies towards a predominance of excitatory processes (-1 scores and +1 scores) also display intermediate tendencies towards the conditioning of excitatory processes over inhibitory processes, and do so in a manner which follows the theoretical concept that the greater the initial predominance of excitatory processes, the faster will the learning occur (thus, subjects with a -1 score learn in a mean number of 14.85 trials while subjects with +1 scores require 20.64 trials to reach criterion).

Taken as a whole, the four results may be seen as a continuum in which the rate at which the discrimination is learned, is a function of the amount of excitatory predominance which is measured by the time estimation task. The discrimination is learned fastest by the most consistent underestimators and slowest by the most consistent overestimators; this is a behavioral fact of the present study. The theoretical interpretation which has been herein proposed to explain these facts appears to be enhanced by the fact that the intermediate findings are in line with the hypothesis that discrimination learning may be conceived as a function of the rate at which excitatory processes are conditioned to a predominance over inhibitory processes. Thus, the general conclusion which may be drawn from these results is that the manifested continuum can be theoretically interpreted as providing evidence for the concept that a fundamental process which occurs during discrimination learning is the rate at which excitatory processes come to be conditioned to a predominance over inhibitory processes.

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RELATIONSHIP BETWEEN HUMAN TEMPORAL BEHAVIOR AND DISCRIMINATION-REVERSAL LEARNING

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TABLE 1 - Original Learning, N=82, $\bar{X}$=19.07

UNDERESTIMATORS	OVERESTTIMATORS
N=48 $\bar{X}$=12.93	N=34 $\bar{X}$=27.73
$\bar{X}_1-\bar{X}_2$=14.80 trials T=3.36; p<.005 r=0.45; p<.005	

TABLE 2 - Reversal Learning, N=82, $\bar{X}$=34.32

UNDERESTIMATORS	OVERESTIMATORS
N=48 $\bar{X}$=30.50	N=34 $\bar{X}$=39.73
$\bar{X}_1-\bar{X}_2$=9.23 trials T=1.41; N.S. p=.07 r=0.16; N.S. p=.08	

TABLE 3 - Total Learning, N=82, $\bar{X}$=53.63

UNDERESTIMATORS	OVERESTIMATORS
N=48 $\bar{X}$=43.56	N=34 $\bar{X}$=67.85
$\bar{X}_1-\bar{X}_2$=24.29 T=2.81; p<.005 r=0.35; p<.005	

TABLE 4 - Consistency Scores

	Consistency Scores			
	-3	-1	+1	+3
Trials to Original Criterion	11.33	14.85	20.64	33.10